Los Alamos Dynamics Summer School

Program Description

Over the last 20 years there has been a 20% decline in the number of engineering degrees granted while university degrees in general have increased approximately 20%. Engineering dynamics, which encompasses areas such as flight dynamics, vibration isolation for precision manufacturing, earthquake engineering, blast loading, signal processing, experimental modal analysis, etc. is naturally affected by this decrease in numbers. The effects of this trend are even more pronounced when one considers that most engineering dynamics positions at national laboratories require advanced degrees and are limited to US citizens. Currently, approximately 35% of engineering master of science (MS) and 50% percent of engineering graduate school students are foreign nationals.

The competition for talented individuals with the background necessary to replace those leaving the field of engineering dynamics necessitates a proactive approach of identifying, motivating, and educating students who are embarking on their graduate school careers. The Los Alamos Dynamics Summer School was designed with this proactive approach in mind. The program is designed not only to benefit the students through their educational experience, but also to motivate them to attend graduate school and to make the students aware of career possibilities at DOE laboratories after they have completed their graduate studies.

The summer school has two focus areas. First, the multidisciplinary nature of research in engineering dynamics is emphasized throughout the summer school. To this end, the students were assigned to diverse teams and given a project where a coupled analytical/experimental approach to dynamics problems is required. Second, the program is designed to develop the students' written and oral communications skills. To develop these skills, the students were required to give numerous informal oral presentations of their work as it progressed throughout the summer and culminating in a formal presentation and a paper written for the International Modal Analysis Conference.

Student Body Profile

This program primarily targets university juniors and seniors who have achieved sufficient academic success to be credible candidates for graduate school. First-year graduate students are also targeted for this program. The summer school was taught for the second time in the summer of 2001 to twelve students. Two of the students have completed their first year of graduate school, two are starting graduate school in the fall, and eight will be seniors next year. The students were mostly mechanical (9) or civil engineering majors (2), and there was one aerospace engineering major. Two of the students were women or underrepresented minorities. The grade point average (GPA) for the students was 3.6 on a scale of 4.0. Undergraduate institutes that were represented by these students included Rose-Hulman Institute of Technology, Case Western Reserve University, University of Houston, Purdue University, Colorado State University, University of California-Irvine, Montana State University, and Texas Tech University. Graduate schools represented by these students (where they currently attend or will attend in the Fall) include Texas Tech University, Purdue University, Cornell University, and University of Wisconsin-Madison.

Program Projects

The centerpiece of the summer school was an eight-week project having both an analytical and

an experimental component. The experimental component was a critical aspect of the program because practical experimental activities in engineering dynamics are almost nonexistent at the undergraduate level. Students were placed in teams of three people and assigned a project. An attempt was made to make the teams as multidisciplinary and diverse as possible. To this end, students from the same school were not assigned to the same team. Each team had a mentor from Los Alamos National Laboratory or Sandia National Laboratory technical staff. The mentors worked closely with their groups providing guidance, encouragement, and technical expertise. All of the projects resulted in papers to be presented at the 2002 International Modal Analysis Conference. The titles of the resulting papers and their abstracts are listed below.

Effects of Bearing Surfaces on Lap Joint Energy Dissipation

Abstract: Energy is dissipated in mechanical systems in several forms. The major contributor to damping in bolted lap joints is friction, and the level of damping is a function of stress distribution on the bearing surfaces. This study examines the effects of bearing surface configuration on lap joint energy dissipation. The examination is carried out through the analysis of experimental results in a nonlinear framework. Then nonlinear finite element models are constructed to simulate the results. The experimental data were analyzed using piecewise linear log decrement. Phenomenological and nonphenomenological mathematical models were used to simulate joint behavior. Numerical results of experiments and analyses are presented. The lap joint studied is shown in Fig. 6.

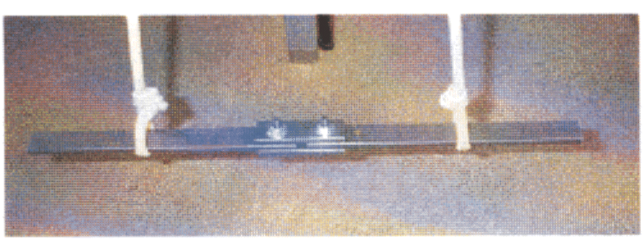

Figure 6. Lap joint studied.

Experimental Modal Analysis and Damage Detection in Simulated Three-Story Building

Abstract: This is a continuation of the paper entitled "Damage Detection In Building Joints By Statistical Analysis" in which accelerometer data were acquired from a simulated three-story building driven by an electrodynamic shaker attached to the base of the structure. Joint damage and environmental conditions were simulated, and data were collected systematically for comparison. Operational variability was introduced by changing the shaker input amplitudes and frequency ranges. A damage-sensitive feature was extracted from the data and a sequential probability ratio test (SPRT) was used to determine when this feature changed as a result of damage. The test was shown to be sensitive to the operational variability and other sources of variability. This investigation was conducted as part of a conceptual study to demonstrate the feasibility of detecting damage in structural joints caused by seismic excitation. A picture of the instrumented structure is shown in Fig. 7.

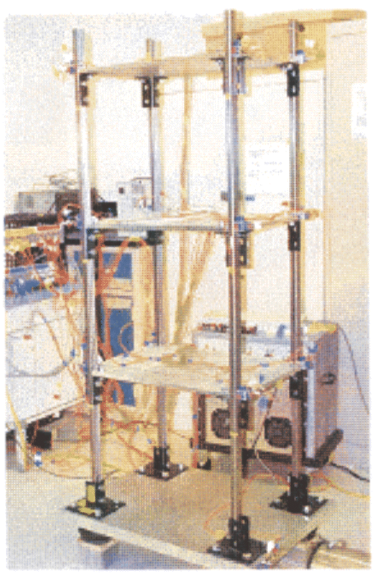

Figure 7. Simple model of a three-story building.

Instrumented 5-DOF System Identifying the Effects of Stiffness Changes in a 5-DOF System

Abstract: Using a system of five masses and four springs, both linear and nonlinear changes in

stiffness were detected by examining the frequency and time response of the system. The replacement of an individual spring with one of a different stiffness value created a linear change, while nonlinearities were introduced through the use of collisions between masses. From the time history of the input force and the accelerations of each mass, the frequency response functions, natural frequencies, mode shapes, power spectra, and probability density functions were calculated. These results were used, in conjunction with a numerical model, to detect changes in the system. In general, the natural frequencies and mode shapes were the best identifiers for linear changes, while the power spectra and probability density functions best identified nonlinear changes. The 5-DOF structure is shown in Fig. 8.

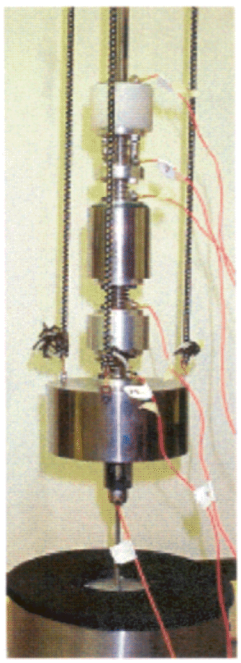

Figure 8. Instrumented 5-DOF system.

Passive Modal Damping with Piezoelectric Shunts

Abstract: The use of piezoelectric materials in conjunction with passive inductance-resistance-capacitance (RLC) circuits to dampen specific vibration modes is explored. The piezoelectric materials convert mechanical energy to electrical energy, which is then dissipated in the RLC circuit through joule heating. An impulse is applied to a simple cantilevered beam and by varying the inductance and resistance values, the natural oscillation frequency for the RLC circuit is tuned to dampen the first mode of vibration. Pictures of the beam and PZT material are shown in Fig. 9.

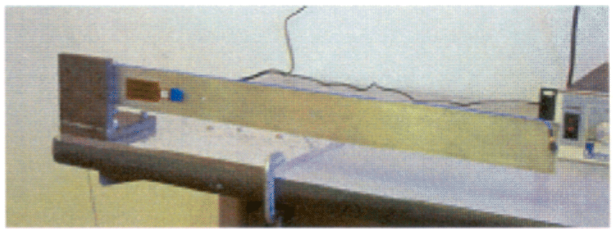

Figure 9. Aluminum beam with piezoelectric shunt.

Experimental Equipment and Software

Students each had their own high-end PC with numerical analysis and signal processing software. The companies donating software are shown in Table 2.

Each research group had access to a multi-channel data acquisition system. Finite element analysis software was made available to each research group as necessary. Equipment on hand at the start of the summer school included

Table 2. Companies Donating Software for the Duration of the Summer School

Company	Software	Purpose
Mathworks	Matlab (plus all toolboxes and simulink)	Numerical analysis and signal processing
Ansys, Inc.	ANSYS	Finite element analysis
Vibrant Technology, Inc.	ME'scopeVES	Vibration data analysis

- 14 PCs with MS office and numerical analysis and signal processing software.
- 40-channel HP data acquisition system (Fig. 10), 4-channel Dactron Photon dynamic signal analyzer, two 8-channel Dactron SpectraBook data acquisition systems. (The Photon and one of the SpectraBooks were donated by Dactron for the duration of the summer school.)
- Data acquisition/signal processing software
- Experimental Modal software packages (ME'scopeVES)
- Various sensors, impact hammers, and small shakers were acquired for specific projects
- Finite element software (ANSYS)
- Rigid-body dynamics software package (ADAMS or Working Model)

Field Trips

Several field trips were taken throughout the summer. These trips included tours of the Aging Aircraft Facility, Robotics Facility and Micro-Electromechancial Systems Facility at Sandia National Laboratory. Another field trip to see a rocket sled test at Holloman Air Force base was scheduled for the last week of the summer school, but was cancelled because the test was postponed at the last minute.

Visiting Distinguished Lecturers

Each week a prominent guest lecturer in the field of engineering dynamics gave a talk to the students about "cutting edge research" in structural dynamics. These lecturers and the titles of their talks are listed in Table 3. Most of the lecturers spent two to three days in Los Alamos. In addition to one formal presentation to the students, visiting lecturers spent time with the students discussing their projects and providing suggestions and additional motivation.

Tutorials

In addition to the project and the lectures by, and interaction with, the visiting distinguished scholars, the students received instruction on a variety of topics in engineering dynamics. This instruction took the form of multi-lecture tutorials on general topics such as random vibrations or computational structural dynamics and demonstration/application lectures on more specific topics. The titles of the multi-lecture tutorials are listed in Table 4 and the demonstration/application lectures in Table 5.

Recruiting Strategy

At the onset of the summer school we let the students know that one of the prime reasons for our investment in the summer school was the

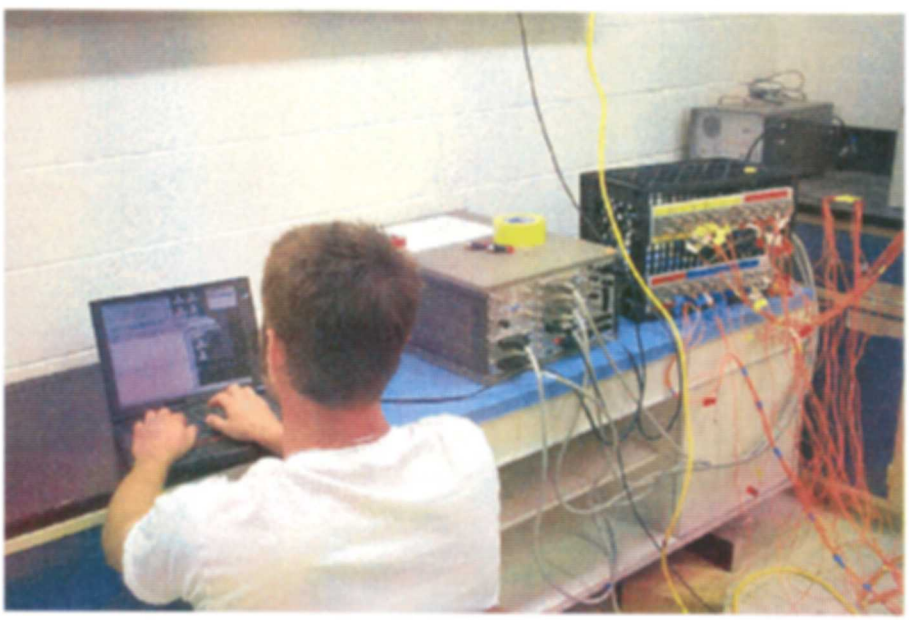

Figure 10. The 40-channel data acquisition system.

Table 3. Distinguished Lecturers

Name	Title, Organization	Title of Talk
Dave Brown	Professor of Mechanical Engineering; Director of the Structural Dynamics Research Laboratory, University of Cincinnati	"Modal Analysis Case Histories"
Dave Ewins	Professor, Director of Center of Vibration Engineering, and Director of the Rolls-Royce University Technology Center for Vibrations, Imperial College, UK	"Vibration Testing in 2001: Who needs vibration tests in this age of supercomputers"
Dan Inman	Director of Center for Intelligent Material Systems and Structures; George R. Goodson Professor of Mechanical Engineering, Virginia Tech	"Smart Structures, Structural Health Monitoring and Control"
Tom Kenny	Associate Professor of Mechanical Engineering, Head of the Micro Structures and Sensors Lab, Stanford University	"Micromechanical Devices for Biological Force Measurements"
Gerry Pardoen	Professor of Civil and Environmental Engineering, President of the Consortium of Universities for Research in Earthquake Engineering, University of California, Irvine	"Earthquake Engineering"
Mike Todd	Head of the Naval Research Laboratory Fiber Optic Smart Structures group	" High-Performance Fiber Optic Sensing"
Geof Tomlinson	Professor; Director, Division of Aerospace Engineering; Director of Research, Engineering and Physical Science Division, University of Sheffield, UK	"Novel Materials/Devices with Application to Vibration Control"

recruitment aspect. We also had several students from the 2000 school discuss their experiences with the school and explain to the new students why they decided to return to the Laboratory the following summer.

Our first goal in the recruitment of these students is to get them to return as graduate research assistants (GRAs) in the summers after they have completed the school. This summer we had five students from the 2000 summer school return in this capacity. Two other students wanted to return, but their advisors required them to stay and work on research projects at their respective universities. Two of the students that did return are spending a year at the Laboratory before they continue on with their graduate studies. The key to the students' return is to stay in contact with them after they return to their universities. In this respect, sponsoring the students to attend the International Modal Analysis Conference is optimal because the conference takes place in early February. We then get to meet with the students and discuss their plans for the upcoming summer. Also, we make it clear to the students that we will write letters of recommendation for them regarding applications to graduate school and applications for graduate fellowships.

Table 4. Titles and Presenters of Multi-lecture Tutorials

Title	Presenter	Title, Organization	Number of Lectures
Rigid Body Dynamics	Phillip Cornwell	Associate Professor, Rose-Hulman Institute of Technology	4
Structural Dynamics	Nick Lieven	Reader in Dynamics, Head of the Dynamics and Controls Group and Director of Research for the Department of Aerospace Engineering, Bristol University, UK	5
Experimental Modal Analysis	Pete Avitabile	Assistant Professor of Mechanical Engineering; Founder and President of Dynamic Decision, University of Massachusetts, Lowell	5
Signal Processing	Norm Hunter	Staff Member, Los Alamos National Laboratory	3
Wavelets	Amy Robertson	Staff Member, Los Alamos National Laboratory	2
Controls	Matt Bement	Staff Member, Los Alamos National Laboratory	2
Random Vibrations	Tom Paez	Staff Member, Sandia National Laboratory	5
Nonlinear Vibrations	Doug Adams	Assistant Professor, Purdue University	5
Computational Structural Dynamics	Joel Bennett	Staff Member, Los Alamos National Laboratory	5

Table 5. Additional Instruction

Title	Presenter	Title, Organization	Number of Lectures
Confinement Vessel Blast Analysis	Bob Stephens	Staff Member, Los Alamos National Laboratory	1
Satellite Testing and Analysis	Tom Butler	Staff Member, Los Alamos National Laboratory	2
A Rigid Body Dynamics Code – ADAMS	Scott Doebling	Staff member, Los Alamos National Laboratory	1

If the student is graduating with an M.S. degree or higher within the next year and our group has an opening, or we are aware of other openings at the Laboratory, we arrange an interview for that individual and corresponding group leaders to discuss possible employment. This approach proved successful this year, as we have recruited the first two staff members from the summer school.

It will take another two years before we will have a consistent stream of candidates to place. This delay is directly related to the fact that most students to date have just completed their junior year. This stage of their academic careers is the ideal time for the summer school to impact their decision to attend graduate school. Students at this stage of their careers have another year at the undergraduate level and then approximately two years to complete their M.S. degrees before they become eligible for hire.

Performance Objectives and Milestones

The original performance objectives were:

- Design an eight-week program for a group of 12 upper division, US citizen, undergraduate or first-year graduate students.
- Identify high-quality students from diverse (human/academic) backgrounds.
- Recruit students from universities that emphasize undergraduate education as well as research institutes.
- Seek students from a variety of academic disciplines including aerospace engineering, civil engineering, mechanical engineering, and electrical engineering; computer science; and mathematics/statistics.
- Expose students to the multidisciplinary aspects of structural dynamics through analytical/experimental research projects.
- Develop students' written and oral communications skills.
- Make students aware of career possibilities at DOE DP laboratories.
- Require students to provide written feedback regarding their experiences during the summer school.
- Provide Los Alamos National Laboratory and DOE education programs offices with an annual summary of the summer school and its demographics.
- Maintain an "alumni database" to track the careers of the summer school participants over the next few years. The information contained in this database will be used to quantify the success of the summer school in meeting its intended goals of motivating the students to attend graduate school and pursue careers at DOE DP laboratories.

The milestones identified in the original proposal were met.

- End of November 00
  Obtain DOE funds for FY01 summer school and begin to recruit students.
- End of January 01
  Identify and receive commitments from lecturers, obtain approval for field trips and identify student projects and required equipment/test items.
- End of February 01
  Host student paper session at International Modal Analysis Conference. Identify students for FY00 summer school.
- End of March 01
  Obtain space allocations for summer school. Obtain matching funds and in-kind support.
- End of May 01
  Obtain necessary hardware and software for FY01 summer school.
- Mid June 01
  FY01 summer school.

Of particular significance was the in-kind support provided by leading software and hardware suppliers. MathWorks and ANSYS provided software that would have cost over $100K and Dactron provided data acquisition equipment that would have cost over $30K. These software and hardware donations were crucial to the success of the summer school. Also, the Engineering Science and Applications Division (ESA Division) provided 14 new PCs for the summer school at a cost of over $90K as well as $75K in direct financial support to cover staff members' time while they mentored the students. The Weapons Response Group in ESA provided administrative support, essential to the success of the summer school.

The organizers of the International Modal Analysis Conference (IMAC) have set up a special session for our students to present their papers at the 2002 IMAC Conference. We have obtained support from the Laboratory and the students' various schools so that all the summer school students can attend the IMAC Conference.

Performance Measures

As summarized in the program description, program objectives and milestones originally

defined for this program have been met. The guest lecturers provided oral feedback on the student projects and overall administration of the summer school. This feedback was overwhelmingly positive.

Students were required to provide written feedback regarding their experiences in the summer school program. This written feedback included evaluations of each speaker, field trips, guest lecturers and a final overall evaluation of the summer school. The assessment of each speaker and guest lecturer will be used to decide which speakers to invite back next year as well as to give the individual speakers suggestions on how they can improve their contribution to the summer school. Overall the distinguished lecturers were rated highly with an average score of 4.2 and a median score of 4.4 on a scale from one to five where a one is "poor" and a five is "excellent." One speaker, who the students felt was giving a sales pitch for his own research, pulled down the average score for the distinguished lecturers. The average rating of the speakers giving the week-long lecture series was a 4.4, and the average rating for the speakers who gave just one or two lectures was 4.0. The field trips to the Aging Aircraft Facility, the MEMs Facility and the Robotics Facility at Sandia National Laboratory received ratings of 4.33, 4.78 and 4.33 respectively using the same scale discussed earlier. The average rating of the mentors was a 4.2. The mentors are listed in Table 6.

A summary of the final overall survey is shown in Table 7. Clearly from Table 7 the program benefited students educationally as well as motivating students that had not already decided on attending graduate school to do so. The goal of making students aware of career opportunities at Los Alamos in hopes of recruiting them upon graduation was realized when all 12 of the students indicated a desire to return to the Lab in subsequent summers as graduate research assistants, although several recognized this would probably not be possible due to commitments in graduate school. The fact that all 12 students would encourage someone they know to apply to the program next year is a clear testimony as to how positively the students viewed the program. As can be seen from Table 7, the average overall rating of the summer school was a 4.75. When the students were asked to rate the quality of the teamwork in their groups, three of the groups averaged a score of 4.7, and the final group had an average of 4.0.

Student Comments

"The project was really interesting and I feel that I learned a lot."

"I would just like to say thank you for this fantastic opportunity. I think that the summer school has been a very beneficial experience for all of us. I also think that the summer school's intention of drawing more people to work for the lab has been a success. Keep it up!"

"The DSS was an excellent opportunity to see into a field that is not talked about a whole lot in college."

"Working in Los Alamos has inspired me to do extra work on subjects I wouldn't otherwise cover in school. I am encouraged by the fact that

Table 6. Mentor Summary

Mentor, Affiliation	Area of Expertise
Amy Robertson, ESA-WR	Signal processing and system identification
Chuck Farrar, ESA-WR	Structural health monitoring
Norm Hunter, ESA-MT	Environmental testing and system processing
Tom Paez, Sandia National Lab	Random vibrations

Table 7. Assessment Summary

Question	Average rating
As a result of the program your knowledge and experience in experimental vibrations: (5 –Increased a great deal, 3 – Increased slightly, 1 – Stayed the same)	4.83
As a result of the program your knowledge and experience in analytical methods in vibrations: (5 –Increased a great deal, 3 – Increased slightly, 1 – Stayed the same)	4.75
Prior to the program if you had not already decided to go to graduate school did this program influence you to do so? (If you are already in graduate school or are attending one in the fall please leave blank)	1 yes, 0 no, 1 "I'm strongly considering it" 10 already decided
Would you encourage someone to apply next year?	12 yes, 0 no
Would you be interested in coming back to LOS ALAMOS NATIONAL LABORATORY as a Graduate Research Assistant next summer if a position was available?	9 yes, 3 yes (but won't be able to), 0 no
Overall rating of the summer school? (5 – Excellent, 4 – Very good, 3 – Good, 2 – Fair, 1 – Poor)	4.75

a civil engineering graduate can work on some exciting things in Los Alamos that wouldn't normally be offered to a beginning civil engineer, and I am certain now that I would like to continue school, and do research on dynamics of structures."

"A wonderful experience, I enjoyed all the guest and tutorial lectures."

Even though the overall assessment of the program was overwhelmingly positive, there were a number of suggested improvements. These included

- Reduce overlap in some of the lectures
- Have more field trips
- Provide more information before the summer school begins
- Have more "real world" applications in the tutorials

In the assessment of the 2000 summer school the students made comments concerning reordering of the lectures, changing the lecture times, and the limited or mildly inadequate experimental or computer equipment. Because students did not comment on these topics this year, we feel that changes made to the program adequately addressed these concerns.

Critical Skills and DOE/DP Mission Benefit

We proposed this summer school concept because engineering dynamics is an integral part of the Laboratory's nuclear weapons stockpile stewardship responsibility. For example, the Engineering Science and Applications Division has over 100 engineers involved in some type of weapons-related engineering dynamics project that include such critical skills areas as engineering design and evaluation, environmental testing, and high-performance computing and simulation. We believe this program will also make the students aware of these career possibilities at DOE Defense Programs (DP) laboratories after they have completed their graduate studies. To this end, all students that participated in the 2000 and 2001 summer schools plan to attend graduate school, and they all expressed interest in returning to the Laboratory. Five of the 2000 students have returned to the Laboratory as GRAs during the summer of 2001. The Weapons Response Group is actively recruiting two students from the 2000 class for a staff positions.

Highlights of This Year's Accomplishments

The program has achieved its primary goals of introducing a talented group of engineering students to both analytical and experimental engineering structural dynamics and of making them aware of career opportunities at DOE DP laboratories. Of particular note, this last goal was further addressed when five students from the first summer school returned to the Laboratory this past summer. Also, the Laboratory has offered full-time staff member positions to two students from the 2000 class. One will graduate with a M.S. degree in mechanical engineering from Georgia Tech. This student had a 3.97 undergraduate GPA at Rose-Hulman Institute of Technology. For the past two years Rose-Hulman has been ranked by *US News and World Report* as the #1 engineering school in the US without a Ph.D. program.[1] The other student will graduate with an M.S. degree in aerospace engineering from Stanford University after obtaining a BS degree from MIT *US News and World Report* ranks Stanford and Georgia Tech as the 2nd and 5th best engineering graduate schools, respectively.[2] Clearly, the recruiting aspect of the summer school is already paying dividends as both these students have verbally accepted this offer. In addition, a third student from the 2001 summer school who will graduate in the spring of 2002 with an M.S. degree in engineering physics from the University of Wisconsin–Madison has recently requested an interview. These recruiting accomplishments directly address the issues raised in the Chiles Commission Report regarding Recommendation #7, "Establish and Implement Plans on a Priority Basis for Replenishing Essential Technical Work Force Needs in Critical Skills."

The student groups produce quality papers that will be presented at the International Modal Analysis Conference. A culminating highlight of the summer school was the oral presentations that the students made to the staff in the Engineering Science and Applications Division. Managers in this division noted that the student presentations were of the quality that the staff would give for a high-level program review in the nuclear weapons directorate. The students' conference papers, their viewgraphs, and detailed summer school information can be viewed at www.lanl.gov/projects/dss.

A paper about the summer school entitled "The Los Alamos National Laboratory Dynamics Summer School—A Mechanics Motivator" was presented at the Annual American Society of Engineering Educators Conference this past June. This paper won the best paper award in the mechanics section at this conference. Also, managers at Boeing and Caterpillar who saw summer school presentations have both approached Los Alamos about the possibility of sending their new hires to the summer school. This interest further attests to perception by outside organizations that the Laboratory has developed a unique program that fills a void in our engineering education system.

References

[1] See http://www.usnews.com/usnews/edu/college/rankings/engineering/nophd/topprogs_nophd.htm

[2] See http://www.usnews.com/usnews/edu/beyond/gradrank/eng/gdengt1.htm